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A Networked Wizard-of-Oz Experiment to Study the Effect of Communication on Decision-Making Performance

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Verbal communication is a crucial aspect of Naval Command and Control (C^2) environments. In the Combat Information Center (CIC) of Navy ships, the communication load is at times so heavy that it overwhelms the communication net and disrupts the communication process. We began this research to identify verbal communication that could possibly be eliminated or transferred to the computer interface to reduce traffic on the command net. Identifying tasks that can successfully be handled by the computer is especially timely in light of attempts to cut costs through reduced manning efforts. This report describes an experiment to compare human-to-human, human-to-computer, computer-to-human, and computer-to-computer communications. The task is a one-person version of a team decision-making task. The software is a Wizard-of-Oz simulation in which the participant must determine the threat level of two targets. The communication of information and the appropriate acknowledgments can be either verbal or computer generated. The results of an experiment using Naval officers suggest that communication mode affects information-gathering strategies but not the quality of the decisions.

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A NETWORKED WIZARD-OF-OZ[1] EXPERIMENT TO STUDY THE EFFECT OF COMMUNICATION ON DECISION-MAKING PERFORMANCE

INTRODUCTION

The study of decision making in the Combat Information Center (CIC), particularly under stress, has been of particular interest to the Navy since the USS *Vincennes*[2] incident [1]. Verbal communication is a crucial aspect of the Command and Control environment, and the communication load can frequently be so heavy as to overwhelm the entire CIC process. The Combat Information Center [2] of Navy ships is a complex, distributed system composed of multiple computers, with significant human-computer interaction occurring, and several voice communication networks, with a very high degree of human-human communication. This complexity is compounded by the fact that the major command communication network is shared by multiple personnel, each competing for access. Previous studies [3-8] have been conducted to determine the type of work being accomplished via verbal communication, the major participants in each type of work, and which verbal communications might be shifted to the computer to reduce the communication load. In addition to being informative for distributing communication workload in large teams, the study of shifting communication load from human to computer is particularly timely for reduced manning efforts, where computers will be taking on many roles previously assigned to humans.

This software simulation was developed for use in research on decision-making performance when acknowledgments and simple replies are given via the computer interface rather than verbally. This simulation is based on a similar task developed by Hollenbeck and Ilgen [9-11] that was used by multiple participants and aimed primarily at determining the effect of distributed decision-making. The software described here involves only one decision maker who obtains the information relevant to making a decision from distributed sources.

The Experiment

The simulation consists of two networked processes: the subject[3] and the wizard. The participant plays the role of the Anti-Air Warfare Officer (AIR) in the CIC. As such, he[4] is given the task of a decision maker who must collect information about two targets and decide the threat level of each using a two-tiered decision-making process. The role of the two officers (ID and TRK) from whom the information is collected is played by a human-controlled process (the wizard) on a second networked computer.

[1] Wizard-of-Oz experiments substitute a human operator for some component of a computer system in such a way that experiment participants are unaware of the human operator.

[2] On July 3, 1988, over the Persian Gulf, Iran Air Flight 655 was mistakenly identified by the USS *Vincennes* as a hostile Iranian F-14 fighter plane and was shot down, killing all 290 civilians aboard.

[3] In the design of this experiment, the program, machine, and processes associated with the volunteer were labeled "subject" (those associated with the experimenter were labeled "wizard"). For consistency, we continue this usage in the report. When speaking of the human volunteer, we use the term "participant."

[4] For simplicity, we use the masculine form of pronouns to refer to participants (most of whom were male) and the feminine form for the wizard (who was female).

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Participants

The study was conducted using 60 officer volunteers, 50 males and 10 females, who were stationed at the United States Naval Academy during the summer of 1997. The officers' ranks ranged from newly commissioned 01 officers to 06s, and their warfare specialties included surface, aviation, submarine, Marine Corps, and supply. The officers were divided into three groups based on perceived experience: 01 officers with no Fleet experience, officers with surface experience, and all other officers. Twenty 01 officers, 16 surface warfare officers, and 24 other officers participated. Participants were randomly assigned to each of the four modes. Each mode had 15 participants.

TASK DESCRIPTION

Subject Program Description

On each trial, the participant is presented with two targets, for which he must gather information on eight different attributes, determine how threatening the target is, and make a decision about how to deal with the target. In making these decisions, the participant is instructed to deal with the most threatening target first. Appendix A contains the written instructions given to each participant.

The simulation has four possible interaction modes for collecting the attribute information. The responses by the two officers controlled by the wizard can be presented either verbally or as text on the computer screen, and acknowledgments can be made either verbally or by lighting a button on the participant's screen. Table 1 summarizes the four combinations of these modes: Verbal Acknowledgment–Verbal Reply (VAVR), Computer Acknowledgment–Verbal Reply (CAVR), Verbal Acknowledgment–Computer Reply (VACR), and Computer Acknowledgment–Computer Reply (CACR). In the computer response conditions, the participant indicates acknowledgments to the wizard by selecting the acknowledge button on the screen; in the verbal response conditions, the participant's acknowledgments are spoken. In all conditions, the participant queries the wizard for the value of a specific attribute by selecting a labeled button on the screen that corresponds to the attribute value desired. The participant requests values for eight attributes for each of the two targets. The value of a ninth attribute, Identification: Friend or Foe (IFF), is given automatically and is presented visually in all cases.

Table 1 — Summary of the Four Communication Conditions Used in the Experiment

	CACR	CAVR	VACR	VAVR
Wizard Acknowledge	Button light	Button light	Verbal	Verbal
User Acknowledge	Button	Button	Verbal	Verbal
Wizard Response	Text	Verbal	Text	Verbal
User Request	Button	Button	Button	Button

The wizard selects the mode before the experiment starts. Each mode generates a different screen on the participant's machine, as shown in Figs. 1 and 2. Labeled buttons are used to query the values for each attribute. Next to each button is a text box that serves two purposes: the participant may use the box to enter information that is received verbally, or, in the Computer Reply conditions, the value of the requested attribute appears in the corresponding text box. The participant may also enter the

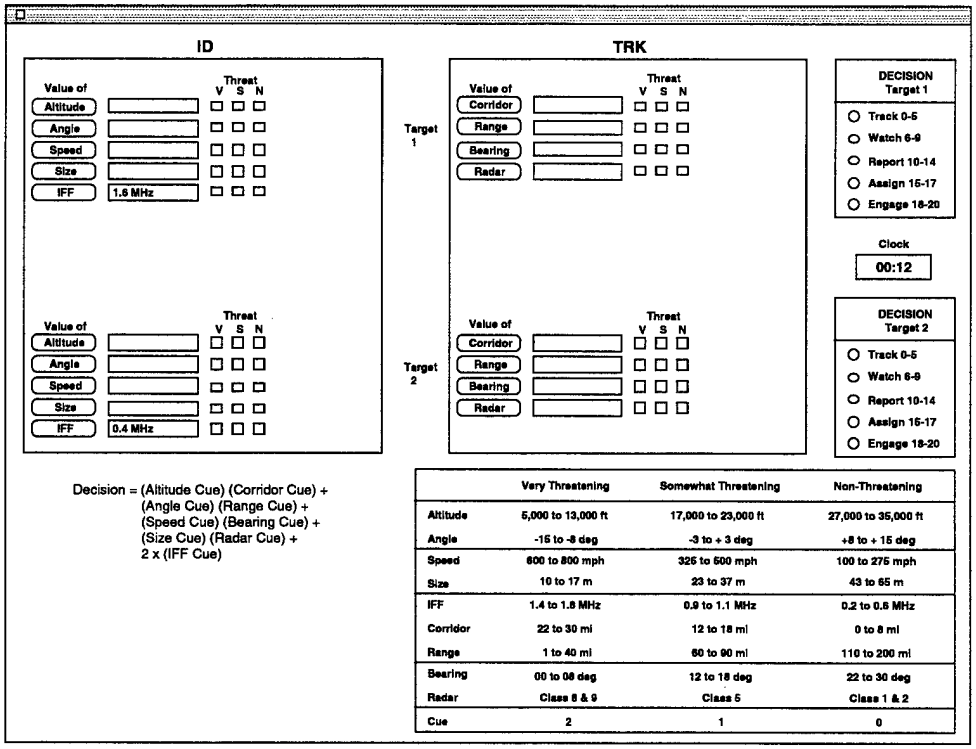

Fig. 1 — The subject's screen for verbal acknowledgment modes VACR and VAVR

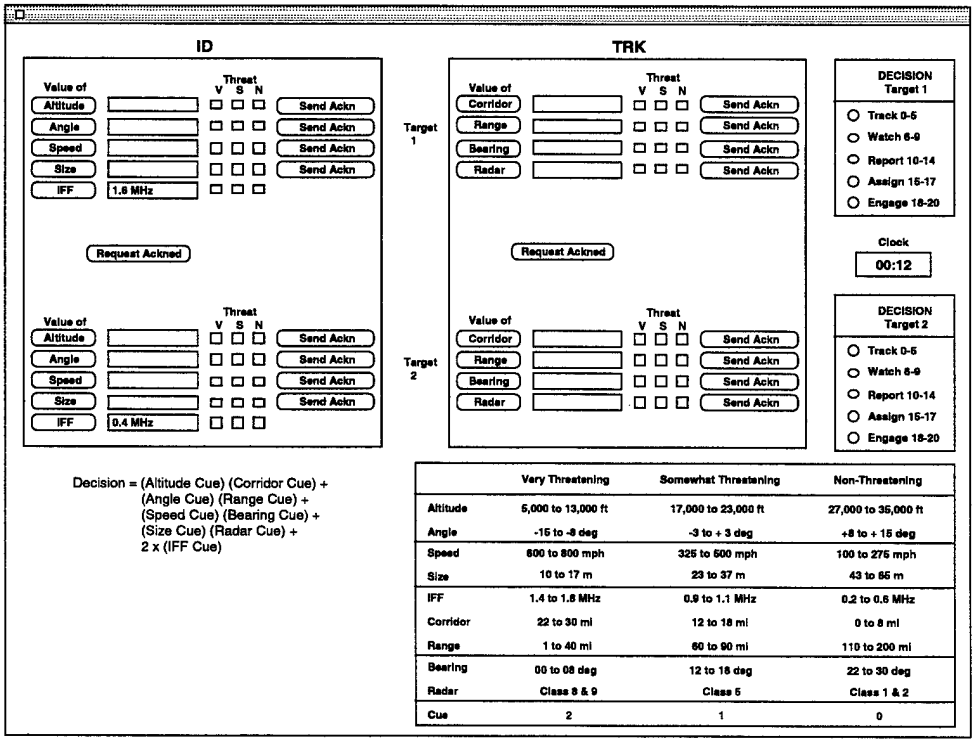

Fig. 2 — The subject's screen for computer acknowledgment modes CACR and CAVR

threat level of an attribute by clicking on one of three threat-level boxes: very threatening, somewhat threatening, or nonthreatening. A clock shows the time elapsed since the start of the trial and is included to provide time pressure, even though there are no actual consequences for not responding quickly. The screen also provides a decision box for each target and the information needed to evaluate threat levels and reach a decision.

The wizard controls information from both the ID and the TRK officers, but it appears to the participant as if he is requesting information from two different team members. In the Verbal Response versions, the two officers are represented by two different voices. Requests for information about Altitude, Angle, Speed, and Size are made to the ID officer and requests for information about Corridor, Range, Bearing, and Radar Class are made to the TRK officer. Information about the ninth attribute, IFF, is always provided visually on the screen and does not have to be requested. When the simulated officers see the request for information, they immediately acknowledge the request. For added realism, delays are sometimes included to simulate the fact that these officers often have other demands on their time. For example, they may need to obtain the information from other sources or may be responding to other requests in the CIC. The reply to a request may be immediate, have a short delay (3.33 s), or have a long delay (6.67 s). On each trial, two randomly selected attributes for each officer will have a short delay, two will have a long delay, and the remaining four attributes will be given immediate responses. Also, to mimic the effects of human fallibility, on two of the eight requests, the simulated TRK does not "notice" the request and fails to acknowledge it. This simulates the effects of high workload or inexperience and requires the participant to repeat the request in order to get the information. TRK always sees the second request and acknowledges it immediately.

The participant must acknowledge the receipt of information in reply to each request. If he fails to do so within 8.33 s, a dialog box appears, asking if he received the reply for the specific attribute. When the dialog box is on the screen, no other work can be done. If the participant answers yes, he may continue to work. If he answers no, the ID or TRK officer will send the information again.

Text boxes are provided for each attribute. In the Computer Reply modes, the reply for each attribute automatically appears in the corresponding text box. In the Verbal Reply modes, the participant has the option of typing the reply in the appropriate text box. For each attribute, there are also check boxes labeled **V**, **S**, and **N** (for very threatening, somewhat threatening, and nonthreatening) that can be used to record the threat level of the attribute. The participant may change the selection after a box has been selected or choose not to use the boxes at all.

There are five possible decisions for a target, in order of increasing severity: Track, Watch, Report, Assign, and Engage. The decision for each target reflects the severity of the threat it poses, based on a two-tiered decision process that combines the threat levels of the nine attributes for that target. A threat score is calculated by first determining the threat level (very threatening, somewhat threatening, or nonthreatening) for each of nine attributes and then combining pairs of attributes according to a simple formula.

The threat levels for the individual attributes (Altitude, Angle, Speed, Size, Corridor, Range, Bearing, Radar Class, and IFF) are determined by comparing their values with the table of "standard" classifications (Table 2)that is provided for reference at the bottom of the participant's screen. Each threat level is associated with a cue value, as shown in the bottom line of Table 2. A very threatening attribute is assigned a cue value of two; a somewhat threatening attribute, a value of one; and a nonthreatening attribute, a value of zero. These cue values are combined, using the formula below, to determine the overall threat posed by the target.

Threat Level = (2 * IFF Cue) + (Altitude Cue * Corridor Cue) + (Angle Cue * Range Cue) + (Speed Cue * Bearing Cue) + (Size Cue * Radar Cue)

Table 2 — Standard Classification Chart

	Degree of Threat		
Attributes	**Very Threatening**	**Somewhat Threatening**	**Nonthreatening**
Altitude	5,000 to 13,000 ft	17,000 to 23,000 ft	27,000 to 35,000 ft
Angle	-15° to -8°	-3° to +3°	+8° to +15°
Speed	600 to 800 mph	500 to 325 mph	275 to 100 mph
Size	10 to 17 m	23 to 37 m	43 to 65 m
IFF	1.4 to 1.8 MHz	1.1 to 0.9 MHz	0.6 to 0.2 MHz
Corridor	30 to 22 mi	18 to 12 mi	8 to 0 mi
Range	1 to 40 mi	60 to 90 mi	110 to 200 mi
Direction	00° to 08°	12° to 18°	22° to 30°
Radar	Class 9 and 8	Class 5	Class 2 and 1
Cue	2	1	0

Unlike in real-world situations, each pair of attributes is weighted equally. This simplification was made so that novices not experienced with Navy command and control decision making could use the task. Even though the decision formula has been simplified to accommodate users without Navy experience, the decision task retains enough realism to be acceptable to more experienced users. The formula arranges the attributes in pairs because they are related. For example, the relationship between Angle and Range can be seen in Table 3. Individually, Angle or Range values may appear to be threatening, but the combination may or may not be threatening, depending on the value of the associated attribute.

Table 3 — The Relationship between Angle and Range

	Angle		
Range	**Descending**	**Level**	**Ascending**
Close	Very threatening	Moderately threatening	Nonthreatening
Intermediate	Moderately threatening	Somewhat threatening	Nonthreatening
Distant	Nonthreatening	Nonthreatening	Nonthreatening

Similar relationships exist between Altitude and Corridor, Speed and Bearing, and Size and Radar Class. Table 4 presents examples of threatening and nonthreatening combinations of attribute values. Multiplying the cue value of one attribute by the cue value of its paired attribute yields a number between 0 (nonthreatening) and 4 (very threatening) that indicates the impact of the two attributes on the decision. Note that if either attribute has a zero cue value, the combination is nonthreatening.

Table 4 — Additional Examples of How the Combined Values of Attributes Determine Threat Levels

Attribute	Very Threatening	Nonthreatening	Nonthreatening
Altitude	low-flying target	high-flying target	low-flying target
Corridor	outside the corridor	outside the corridor	middle of corridor
Speed	fast target	fast target	slow target
Bearing	headed toward ship	headed away from ship	headed toward ship
Size	small target	small target	large target
Radar Class	weapons radar	weather radar	weapons radar

To determine the impact of the IFF value on the decision, the cue value is doubled. If the IFF value identifies a target as a military target (very threatening with cue of 2), it is especially threatening, whereas a civilian target (nonthreatening with cue of 0) is not.

The threat level formula produces a number between 0 and 20. The decision about how to handle the target can then be determined from Table 5.

Table 5 — Values for Making the Target Decisions

Decision	Threat Level
Track	0 - 5
Watch	6-9
Report	10-14
Assign	15-17
Engage	18-20

A decision to *Track* a target means that no further attention needs to be given to this target but the target's ID should remain visible. A decision to *Watch* a target implies that the target should continue to be watched on radar. A decision to *Report* a target means the ship should send a message to the target identifying the ship and alerting the target to steer clear. A decision to *Assign* the target implies the ship should synchronize its radar and attack weapons so that the weapons are fixed on the target. A decision to *Engage* a target requires weapons to be launched.

The participant makes a decision concerning the threat level of the target by selecting a radio button. Although participants are told to deal with the most threatening target first, the order of the decisions has no visible consequences and the participant may change his mind on the first decision. However, as soon as the second decision is made, the trial ends.

Wizard Program Description

Before each participant begins, the wizard selects one of the four modes from the Mode Menu. The wizard also selects the number of trials from a menu when the participant begins. If *Practice* is selected, the participant is given two trials. If *Real Trial* is selected, then the participant is given 10 trials. Appendix B lists the attribute values used in the practice (one scenario, repeated) and the experiment trials.

Although it appears to the participant that he is receiving attribute information from two separate officers, the wizard is actually functioning as both officers. The wizard's screen (Fig. 3) is divided into quarters. Four attributes for the first target are in the upper left quadrant, and the same four attributes for the second target are in the upper right quadrant. The ID officer controls these eight attributes. The other four attributes for the first target are in the lower left quadrant, and the other four attributes for the second target are in the lower right quadrant. These are the attributes controlled by the TRK officer. The ninth attribute, IFF, does not appear because it is displayed automatically on the participant's screen and does not require the wizard's intervention.

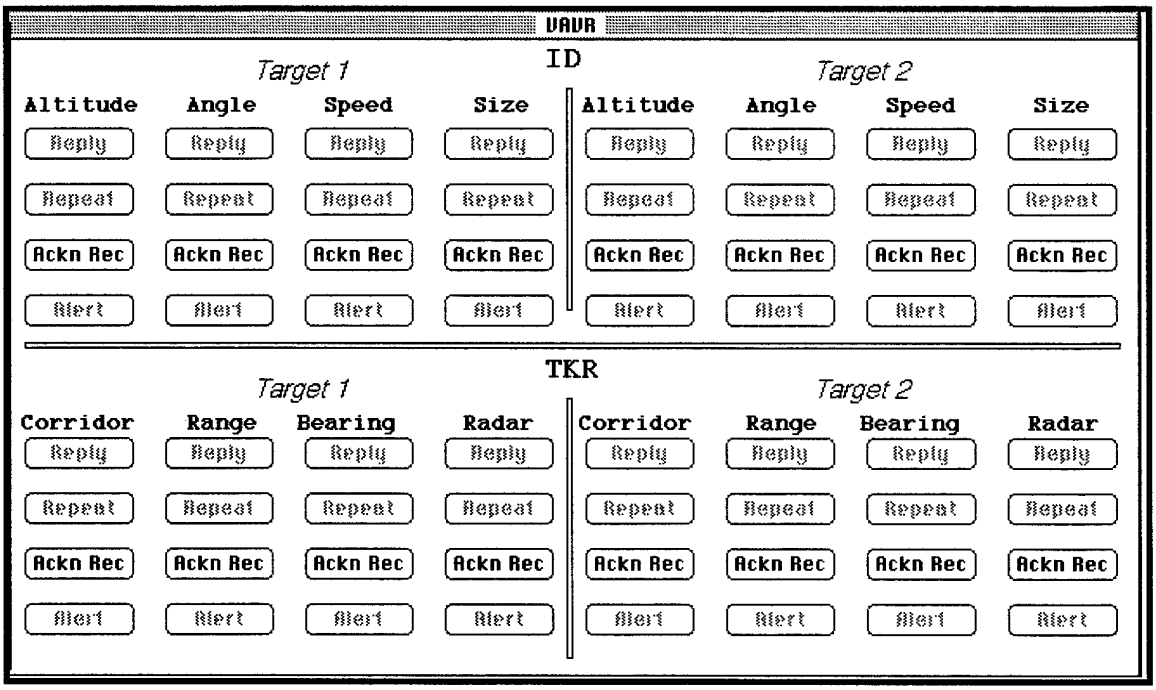

Fig. 3 — The wizard's screen

Each attribute has four buttons associated with it. The *Reply* button becomes highlighted when the participant requests information; the wizard then selects (clicks) the button and this causes the program to send an encoded message to the subject machine. When the subject machine receives this message, the program immediately activates the acknowledgment of the participant's request and determines whether to reply immediately, after a short delay (3.33 s), or after a long delay (6.67 s). If the reply should be delayed, then an alarm is set on the subject machine. Each time the Event Loop enters an idle cycle, the delayed replies are checked to determine if it is time to reply to the participant. When the delay time has elapsed, the reply is finally given to the participant and an alert alarm is set. If the participant does not acknowledge the reply before the alert alarm goes off, then an encoded message is sent to the wizard machine that highlights that attribute's *Alert* button.

When the participant acknowledges a reply, an encoded message is sent to the wizard machine. The wizard machine decodes the message and highlights the appropriate attribute's *AcknRec* button. When the wizard selects the *AcknRec* button, it is disabled and an alert flag for that attribute is set. When the wizard machine receives an alert message, it determines whether the alert flag has been set. If it has, it is toggled and the alert is ignored. If it has not been set, then the *Alert* button is highlighted.

When the wizard selects the *Alert* button, an encoded message is sent to the subject machine that immediately displays a dialog box. The dialog box asks the participant if he received the response for the appropriate attribute. The participant must respond either ***yes*** or ***no*** to the dialog box before he can continue. His answer is then encoded and sent to the wizard machine. If the participant responds yes, then nothing else occurs. If he responds no, then the *Repeat* button for the appropriate attribute is highlighted on the wizard's screen. The wizard selects the *Repeat* button and an encoded message is sent to the subject machine. The subject machine decodes the message and again determines whether the reply should be immediately delivered or delayed. If it is delayed, then the delay routine is executed. If the participant fails to acknowledge this reply, he will receive another alert dialog box.

When the participant has completed both decisions, an encoded message is sent to the wizard machine. This machine then either starts another trial or sends a message to the subject machine to display a summary of the correct decisions and the participant's decisions for each trial.

Modes

As each new participant begins, the wizard must select a mode type from the Mode Menu. Four different modes are available: Verbal Acknowledgment–Verbal Reply (VAVR); Computer Acknowledgment–Verbal Reply (CAVR); Verbal Acknowledgment–Computer Reply (VACR); and Computer Acknowledgment–Computer Reply (CACR). Each mode will bring up a different screen on the subject machine (Figs. 1 and 2).

All of the wizard's verbal acknowledgments and verbal replies are prerecorded sound files that are stored on the subject machine. Whenever the wizard selects a *Reply* button, an encoded message is sent to the subject machine. When the subject machine decodes this message, it immediately acknowledges the participant. In the two Computer Acknowledgment modes, CAVR and CACR, the *RequestAckned* button for the appropriate officer is highlighted on the participant's screen for a short period of time. In the two Verbal Acknowledgment modes, VAVR and VACR, the sound resource for the appropriate officer is played. There is no *RequestAckned* button on screens for the VAVR and VACR modes.

In addition to determining what delay to use before the reply is given, the program on the subject machine also selects the mode for the reply. For VAVR and CAVR, the appropriate sound resource is played; for VACR and CACR, the reply is placed in the text box beside the name of the attribute. There is a text box on the participant's screen beside each attribute name, whether the reply is given verbally or as text, and in either case it is possible for the participant to enter information in the box if desired. It is not necessary for the participant to enter this information; the box is simply provided as a memory aid.

The participant must acknowledge each reply after it is received. In the CAVR and CACR modes, once the reply is delivered, a *SendAckn* button corresponding to the attribute is highlighted. This button remains highlighted until the participant selects it or, if the participant does not acknowledge within the required time, until an alert alarm is triggered. While the button is enabled, the participant can select it, thereby sending an encoded message to the wizard's machine that her reply has been acknowledged. In the VAVR and VACR modes, the participant must verbally acknowledge the reply; he does so by speaking the name of the attribute and the word "aye." For altitude, the participant would respond with "Altitude Aye." In the Verbal Reply modes, the *AcknRec* buttons on the wizard machine are enabled when the trial begins. After hearing the participant verbally acknowledge the

reply, the wizard must select the *AcknRec* button. If the *AcknRec* button is not selected, an alert alarm is triggered. As described earlier, the alert alarm activates a dialog box on the participant's screen that asks if the reply was received.

The participant wears earphones for all four modes. This is realistic for the CIC environment and also helps to filter out distracting noises when the experiment is not conducted in soundproof rooms. Sound files for the VAVR, VACR, or CAVR modes, and also the alert signal for the dialog box in all modes, are heard through the earphones. An added benefit to using earphones to deliver the sound files is that the wizard does not hear them and thus is better able to concentrate and, where appropriate, to listen for verbal acknowledgments.

Data Collection

Both the subject and the wizard machine maintain time-stamped log files of everything the participant and the wizard do during the experiment. Both systems also produce summary files. The subject summary file contains the mode, the trial number, the attributes with a short delay before a reply is delivered, the attributes with a long delay before a reply is delivered, the correct threat-level decision, the participant's threat-level decisions, and the elapsed time in tick counts. The summary file records the number of times each attribute was requested, the number of acknowledgments sent, the number of attribute threat-level check boxes used, the number of times the participant changed his mind about the attribute threat-level, and the number of text boxes used. The wizard summary file contains the mode, the trial number, and the two TRK attributes that needed a second request. In addition, for each attribute it records the number of attribute requests, the number of replies, the number of visual and verbal acknowledgments received, the number of alerts, the number of replies the participant received but failed to acknowledge, and the number of replies the participant failed to acknowledge because he did not see/hear them. Appendix C presents a sample of the data files.

SOFTWARE AND HARDWARE CONFIGURATION

Software Development

This software was developed in C++ using the Metrowerks CodeWarrior 11 Integrated Development Environment on a Power Macintosh 8500/180 with 98 MB RAM using 68K emulation and a Macintosh Quadra 800/33 with 48 MB RAM. The code files are available on-line at <http://www.aic.nrl.navy.mil/papers/1999/>. The communication software used is a modification of the CTB code developed by Mark Chally for his Happy Face program [12] and can be downloaded from <http://home.earthlink.net/~chally/>. The asynchronous sound software used is ASndPlayer.c, which was developed by Manuel Pérez-Quiñones as part of the Intelligent Cockpit Project at the Naval Research Laboratory [13].

The Wizard application needs 347 KB of storage while the Subject application requires 7.5 MB of storage, mainly due to the large size of the sound resource file. If it is necessary to change the source code for this simulation, the following things should be noted. The CodeWarrior IDE partition size was set at 7 MB for the Wizard code and 26 MB for the Subject code. If the source code needs to be edited and the debugger used, the size of the partitions needs to be increased. Virtual memory was turned on for both machines and the RAM allocation thereby doubled. The minimum heap size, found in the Edit/Project Settings/Project/68K Project menu, was set at 3 MB for the Wizard and 21 MB for the Subject. The heap in the Subject code is that large due to the sound resources embedded in the Subject project. If the source code is recompiled and a link error occurs that indicates insufficient space in the heap zone, the heap size must be increased.

If modifications are made to the communications, the CTB code may need to be modified. The CTB code only allows for one byte to be passed between machines. Since there are eight attributes, numbered 0 to 7, and two targets, numbered 0 to 1, it takes three bits to pass the attribute number and one bit to pass the target number. This only leaves four bits to encode the type of message being

passed, thereby limiting the number of different types of messages that can be passed between the two machines. This limitation had a definite impact on the design of the simulation.

Appendix D describes the networking configuration and initialization procedures for execution of the program.

Hardware Configuration

The computers were networked together with a LocalTalk cable connecting their printer ports. If the machines are already connected to Ethernet, that connection may remain in place. The Mac-to-Mac LocalTalk cable may also remain in place. Four extensions were added to the Extensions Folder of the System Folder. *ADSP* and *AppleTalk ADSP Tool* are necessary for the communications to work and are available on the Macintosh homepage. *MetroNub* is required if it necessary to recompile or edit the source code; *CFM-68K Runtime Enabler* is also required if the Macintosh is not a PowerPC model. These are provided in Metrowerks CodeWarrior 11.

RESULTS

Several performance measures were collected and analyzed. These included the total time to complete each scenario, the number of correct decisions, and the number of repeated requests. A more detailed analysis of the order in which attributes were requested was used to assess user strategies in collecting target information.

Time to Complete the Task

The time to complete the task was faster for text (computer) responses than for verbal responses (Fig. 4), and there was an overall trend toward completing the task faster over trials. Whether acknowledgments were made verbally or by computer had little effect on the time it took to complete the task. However, for the last trials, when participants were the most practiced, the VAVR group was the slowest to complete the task. An analysis of variance (Table 6) showed significant effects due to response mode, F (1, 56) = 27.45, $p < 0.001$, and trials, F (9. 504) = 46.58, $p < 0.001$, and no other significant effects or interactions.

Participants may have taken longer in the verbal response conditions due in part to the fact that responses took longer to say than to display, and this would also be true when verbal responses are used in real situations. However, a greater proportion of the additional task time was probably taken up by the participants typing in the spoken attribute values. The task could be performed accurately without this extra typing by simply clicking the appropriate threat level box corresponding to the attribute value, given that threat levels, not attribute values, were used in the formula used to decide how to deal with the target. However, most people in the verbal response conditions typed in the attribute values and only looked up the threat values after they had collected the attribute data. The verbal response condition caused the user to take extra steps that were not needed in the computer response condition.

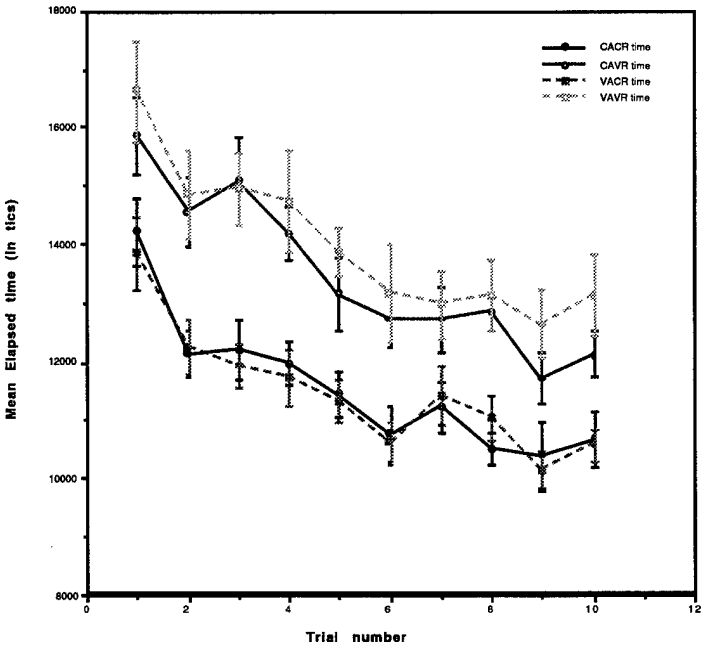

Fig. 4 — Average time to complete the task over trials for each group

Table 6 — Analysis of Variance for Total Elapsed Time

	BETWEEN SUBJECTS				
SOURCE	**Sum of Squares**	**Degrees of Freedom**	**Mean Squares**	***F* Ratio**	**Probability**
Ackn. format	7453107	1	7453107	0.276	0.602
Resp. format	741371000	1	741371000	27.425	0.000
Ackn. format X Resp. format	12210000	1	12210000	0.452	0.504
Error	1513820000	56	27032600		
	WITHIN SUBJECTS				
SOURCE	**Sum of Squares**	**Degrees of Freedom**	**Mean Squares**	***F* Ratio**	**Probability**
Trials	753835000	9	83759500	46.578	0.000
Trials X Ackn. format	4386244	9	487360	0.271	0.982
Trials X Resp. format	20372200	9	2263580	1.259	0.257
Trials X Ackn. format X Resp. format	8815314	9	979479	0.545	0.842
Error	906330000	504	1798273		

Correct Decisions

Communication mode had little or no effect on the number of correct decisions (Fig. 5 and Table 7), and the number of correct decisions also did not change systematically over trials. A 2×2×10 analysis of variance (Table 8) showed no significant effects or interactions due to acknowledgment mode, response mode, or trials ($F < 1.0$ for all effects). This is a very positive result and indicates that the officers were able to make good decisions even under conditions where communicating required more time and effort.

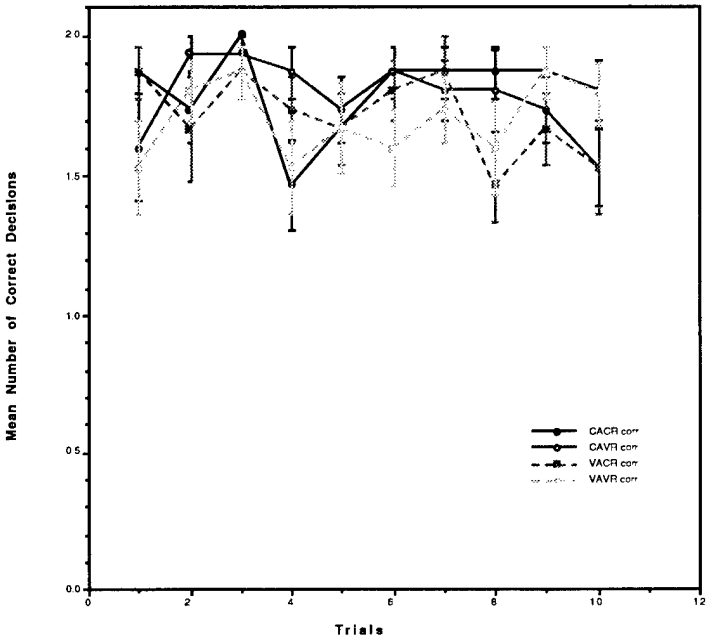

Fig. 5 — Average number of correct responses by trials for each of the four groups

Table 7 — Total Number of Correct Responses for Each Group

	Acknowledge			
	Computer		Verbal	
Response	Mean	Std. Error	Mean	Std. Error
Text	18.00	0.414	17.13	0.380
Verbal	17.80	0.380	17.00	0.602

Table 8 — Analysis of Variance for Number of Correct Responses

SOURCE	Sum of Squares	Degrees of Freedom	Mean Squares	*F* Ratio	Probability
Ackn. format	10.417	1	10.417	2.039	0.159
Resp. format	0.417	1	0.417	0.082	0.776
Ackn. format X Resp. format	0.017	1	0.017	0.003	0.955
Error	286.133	56	5.110		

Repeated Requests

When the response is delayed, a request may be repeated, either because the participant thinks the request has not been received or because the requested information may have been forgotten. Response format significantly influenced the number of repeated requests, with more repeated requests for verbal responses. As expected, the number of repeated requests increased significantly as a function of delay and there was also a significant interaction of delay with acknowledgment format (Fig. 6 and Table 9).

When there is no delay, the attribute information arrives almost immediately, so the acknowledgment modality has little effect. However, the verbal response has an increased probability of being forgotten, and for this reason, the attribute request may need to be repeated. Verbal responses are more transient, and the specific new information that is conveyed about the value of the attribute that was queried is therefore more likely to be forgotten (or lost from short-term memory). This is even more of a problem if there is a delay between the query and the response. There is then the added possibility that the query is no longer actively in short-term memory, and the user must then register both which attribute is being addressed and its value.

Verbal acknowledgments (no new information) are more likely to capture attention, even when the person is looking at another part of the screen and are, therefore, more likely to be noticed. With short delays, a verbal acknowledgment is more likely to have been noticed than a computer acknowledgment and the person is less likely to repeat a request, whereas if the computer acknowledgment isn't noticed, they are more likely to repeat the request because they think it has not been received. With long delays, an added negative effect of verbal acknowledgments is that the person may no longer remember which attribute they requested. If the query is no longer actively in short-term memory, the person must then process which attribute is being addressed as well as its value. Also with long delays, there is a tradeoff between the positive effects of verbal acknowledgments and the negative effects of verbal responses.

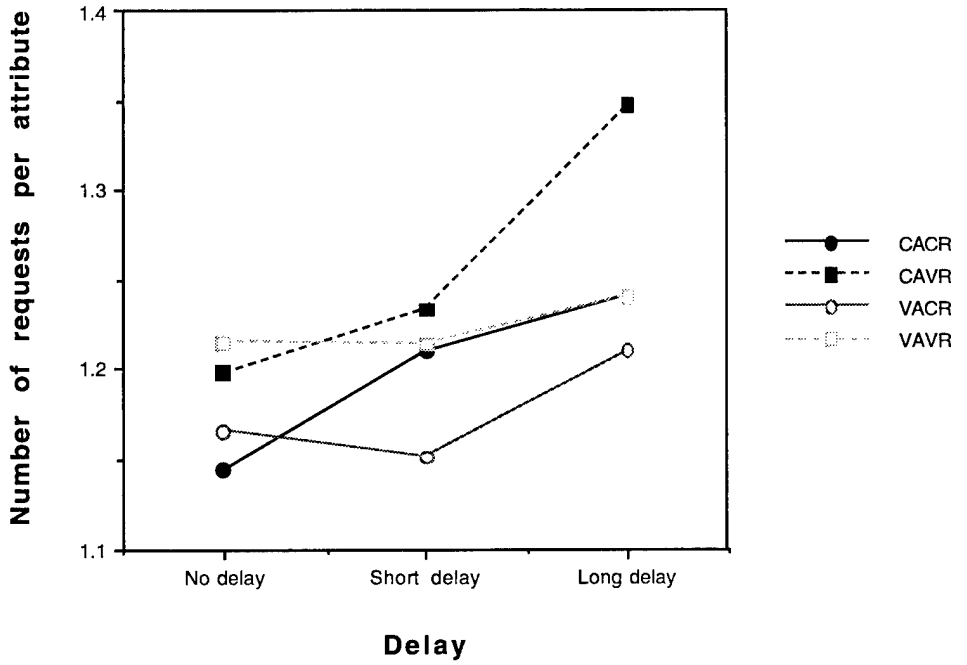

Fig. 6 — Average number of requests per attribute for each of the four groups

Table 9 — Analysis of Variance for Number of Repeated Requests

	BETWEEN SUBJECTS				
SOURCE	**Sum of Squares**	**Degrees of Freedom**	**Mean Squares**	***F* Ratio**	**Probability**
Ackn. format	0.029	1	0.029	1.702	0.197
Resp. format	0.097	1	0.097	5.702	0.020
Ackn. format X Resp. format	0.000	1	0.000	0.001	0.972
Error	0.957	56	0.017		
	WITHIN SUBJECTS				
SOURCE	**Sum of Squares**	**Degrees of Freedom**	**Mean Squares**	***F* Ratio**	**Probability**
Delay	0.134	2	0.067	13.559	0.000
Delay*Ackn. format	0.039	2	0.020	3.953	0.022
Delay*Resp. format	0.007	2	0.003	0.696	0.501
Delay*Ackn. format *Resp. format	0.003	2	0.002	0.332	0.718
Error	0.554	112	0.005		

Strategies for Evaluating Targets

Participants were told to deal with the most threatening target first. There were individual differences in collecting information about the two threats, as well as changes over time (Fig. 7). The number of attributes requested before completing the decision on the most threatening target generally tended to decrease over trials, with the exception of scenarios 2 and 10. All four groups showed the same pattern of change over trials.

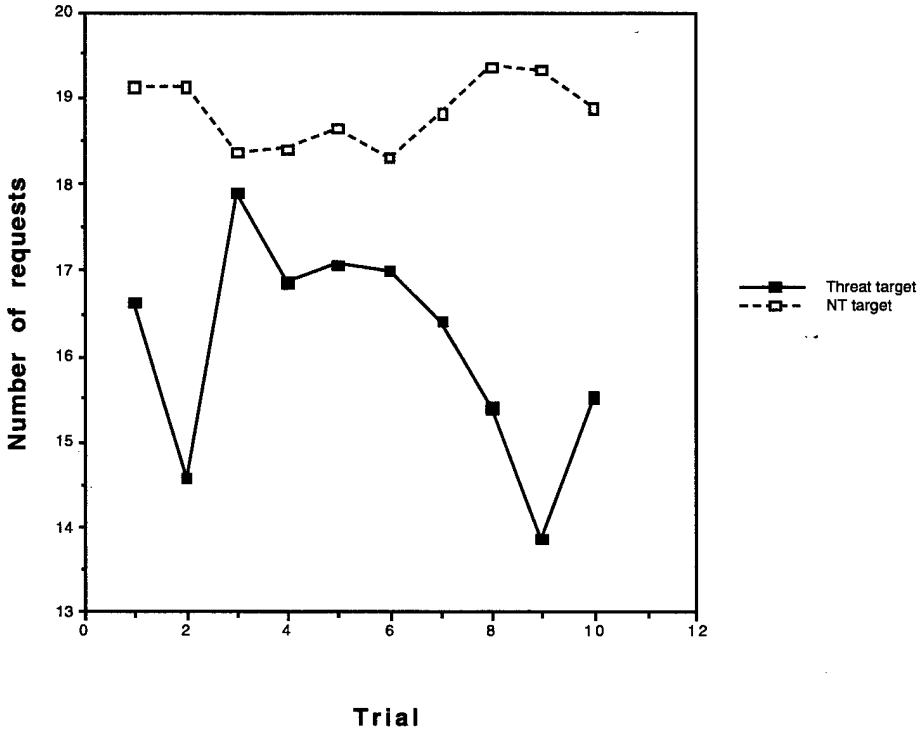

Fig. 7 — Total number of attribute requests before decision for each target type

Table 10 — Number of Trials on which All Attributes on Both Targets Were Requested Before Making the Decision on Either Target

	Acknowledge			
	Computer		Verbal	
Response	Mean	Std. Error	Mean	Std. Error
Text	5.00	1.01	3.87	0.89
Verbal	3.73	0.80	4.60	0.99

Overall, the mode of communication did not significantly affect the order in which decisions were made about each of the two targets. As shown above in Table 10, participants in the CAVR and VACR conditions were somewhat more likely to request all attributes before making a decision on the most threatening target, and, as a result, they also made fewer threat decisions before requesting the

remaining attributes (Table 11). However, these differences were not consistent across either response mode or acknowledge mode, and they were relatively small and were not statistically significant.

Table 11 — Number of Trials on which the Decision on the Most Threatening Targets Was Made Before Requesting the Remaining Attributes on the Less Threatening Target

	Acknowledge			
	Computer		Verbal	
Response	Mean	Std. Error	Mean	Std. Error
Text	4.47	0.81	5.33	0.75
Verbal	5.53	0.68	4.73	0.90

CONCLUSIONS

This software was developed to study the effects of communication mode on information gathering and decision making in a command and control context. A study using this software was conducted using Navy officers stationed at the United States Naval Academy. The results of the study showed no significant change in the accuracy of the threat-level decision made, but strategies and the time it takes to make the decision were significantly affected by communication mode.

- Communication mode affects information gathering strategy and the time taken to complete the task, but it does not affect threat level assessment or the quality of the final decisions.
- Presenting numerical information in text or visual form helps to reduce memory load and reduces the need for repeated requests.
- In cases where there is a delay before a response is received, acknowledgments are very important and they should be in a form that will be attended. Unless auditory overload is a serious problem, verbal acknowledgments are preferable.

The results of this study will be used to determine the feasibility of transferring certain information that is currently delivered verbally in the CIC to the computer interface. This has important implications for reduced manning efforts. A second study using civilians will compare the performance of civilian users with that of Navy officers. The outcome of the second study will have important implications for the Navy's use of civilians in research to test the technology that is to be used in the Fleet.

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Appendix A

PARTICIPANT INSTRUCTIONS

INSTRUCTIONS

All Conditions

In this experiment you will be playing the role of an Anti-Air Warfare Officer deciding how to interact with two unidentified targets in your airspace. You will make this decision by combining information about nine attributes of the target. You will request this information from "ID" and "TRK" officers in the Combat Information Center (CIC). As shown on your screen, the attributes are *Altitude*, *Angle*, *Speed*, *Size*, *Corridor*, *Range*, *Bearing*, and *Radar*. The value of the ninth attribute, *IFF* (Identification: Friend or Foe) is always given and does not need to be requested. To request the value of an attribute, you must use the mouse to click in the box containing the name of that attribute.

VAVR Only

The CIC will verbally acknowledge your request for an attribute value through the headphones. The ID officer will acknowledge your request by saying "ID aye" and the TRK officer will acknowledge by saying "TRK aye."

The ID and TRK officers are receiving requests from other Naval personnel and command centers at the same time you are querying them. If they have heard your request they will immediately acknowledge it, but if they do not acknowledge immediately, then you should assume they have not heard you and should query again. The CIC must sometimes query others for the answer to your request, so if they have acknowledged your request just wait for the answer. The ID or TRK officer will verbally deliver the attribute value through the headphones.

If it is helpful to you, you have the option of clicking on the empty text box to the right of the attribute name and typing in the attribute value. No cursor will appear in this box, but you can still type there.

You must verbally acknowledge receipt of the attribute information by saying aloud "*the name of the attribute* aye." For example, if you have just received the information for range, you would say, "range aye." If you fail to promptly acknowledge the CIC's delivery of attribute information, the CIC will respond with an alert. It will be displayed in a window in the lower left of your screen and will ask if you have received the information. If you reply YES to the alert, you are saying that you have received the information. If you reply NO, the information will be delivered again. You must reply to this alert before going on with the experiment.

CAVR Only

Your request will be acknowledged by the CIC highlighting the **Request Ackned** box briefly. The **Request Ackned** box on the ID side of the screen will become highlighted if you are asking about an ID attribute, and the box on the TRK side of the screen will become highlighted if you are asking about a TRK attribute.

The ID and TRK officers are receiving requests from other Naval personnel and command centers at the same time you are querying them. If they have heard your request, they will immediately acknowledge it, but if they do not acknowledge immediately, then you should assume they have not heard you and should query again. The CIC must sometimes query others for the answer to your request, so if they have acknowledged your request, just wait for the answer. The ID or TRK officer will verbally deliver the attribute value through the headphones.

If it is helpful to you, you have the option of clicking on the empty box to the right of the attribute name and typing in the attribute value. No cursor will appear in this box, but you can still type there.

You must acknowledge receipt of the attribute information by clicking the **Send Ackn** box corresponding to that attribute. If you fail to promptly acknowledge the CIC's delivery of attribute information, the CIC will respond with an alert. It will be displayed in a window in the lower left of your screen and will ask if you have received the information. If you reply YES to the alert, you are saying that you have received the information. If you reply NO, the information will be delivered again. You must reply to this alert before going on with the experiment.

VACR Only

The CIC will verbally acknowledge your request for an attribute value through the headphones. The ID officer will acknowledge your request by saying "ID aye," and the TRK officer will acknowledge by saying "TRK aye."

The ID and TRK officers are receiving requests from other Naval personnel and command centers at the same time you are querying them. If they have heard your request they will immediately acknowledge it, but if they do not acknowledge immediately, then you should assume they have not heard you and should query again. The CIC must sometimes query others for the answer to your request, so if they have acknowledged your request, just wait for the answer. The ID or TRK officer's reply will appear in the empty box to the right of the attribute name.

You must verbally acknowledge receipt of the attribute information by saying aloud "*the name of the attribute* aye." For example, if you have just received the information for range, you would say, "range aye." If you fail to promptly acknowledge the CIC's delivery of attribute information, the CIC will respond with an alert. It will be displayed in a window in the lower left of your screen and will ask if you have received the information. If you reply YES to the alert, you are saying that you have received the information. If you reply NO, the information will be delivered again. You must reply to this alert before going on with the experiment.

CACR Only

Your request will be acknowledged by the CIC highlighting the **Request Ackned** box briefly. The **Request Ackned** box on the ID side of the screen will become highlighted if you are asking about an ID attribute and the box on the TRK side of the screen will become highlighted if you are asking about a TRK attribute.

The ID and TRK officers are receiving requests from other Naval personnel and command centers at the same time you are querying them. If they have heard your request, they will immediately acknowledge it, but if they do not acknowledge immediately, then you should assume they have not heard you and should query again. The CIC must sometimes query others for the answer to your request, so if they have acknowledged your request, just wait for the answer. The ID or TRK officer's reply will appear in the empty box to the right of the attribute name.

You must acknowledge receipt of the attribute information by clicking the **Send Ackn** box corresponding to that attribute. If you fail to promptly acknowledge the CIC's delivery of attribute

information, the CIC will respond with an alert. It will be displayed in a window in the lower left of your screen and will ask if you have received the information. If you reply YES to the alert, you are saying that you have received the information. If you reply NO, the information will be delivered again. You must reply to this alert before going on with the experiment.

All Conditions

You must determine whether each attribute value is *Very Threatening*, *Somewhat Threatening*, or *Nonthreatening*. The standard classification chart in the lower right of the screen will help you to make this determination. If a value falls between threat categories shown on the chart, you must decide which category level is most appropriate. You may place a check in the attribute level check box "**V**," "**S**," or "**N**" to indicate whether that attribute is *Very Threatening*, *Somewhat Threatening*, or *Nonthreatening*, respectively. Checking these boxes is optional and is provided to help you remember and organize your attribute threat information.

To determine how you will interact with the target, you must use the equation in the lower left of the screen to calculate a numerical value. Attribute threat level is represented by a cue value in the equation (e.g., "Altitude Cue"). An attribute that is *Very Threatening* is assigned a numerical value of 2; *Somewhat Threatening* is 1; and *Nonthreatening* is 0. These cue values are shown on the last line of the chart in the lower right of the screen.

Please focus on accuracy in this task, rather than speed.

Appendix B

SCENARIO FILES

Practice 1

20000 ft
-10 dgs
700 mph
13 m
1.6 MHz
13 mi
25 mi
28 dgs
5 class
21000 ft
1 dgs
200 mph
60 m
0.4 MHz
13 mi
75 mi
6 dgs
8 class

Scenario 1

20000 ft
-8 dgs
300 mph
12 m
0.6 MHz
12 mi
125 mi
28 dgs
8 class
7000 ft
-3 dgs
475 mph
14 m
1.6 MHz
16 mi
65 mi
1 dg
9 class

Scenario 2

11000 ft
0 dgs
625 mph
15 m
1.7 MHz
24 mi
22 mi
5 dgs
9 class
21000 ft
2 dgs
650 mph
27 m
1 MHz
18 mi
80 mi
13 dgs
5 class

Scenario 3

30000 ft
3 dgs
650 mph
60 m
1.1 MHz
28 mi
61 mi
24 dgs
1 class
18000 ft
-3 dgs
775 mph
32 m
1 MHz
15 mi
83 mi
4 dgs
5 class

Scenario 4

6000 ft
-11 dgs
600 mph
11 mi
1 MHz
22 mi
75 mi
2 dgs
9 class
12000 ft
10 dgs
710 mph
32 m
0.9 MHz
26 mi
15 mi
7 dgs
8 class

Scenario 5

23000 ft
-15 dgs
650 mph
10 m
1.1 MHz
29 mi
35 mi
17 dgs
2 class
5000 ft
1 dg
250 mph
26 m
0.9 MHz
5 mi
64 mi
12 dgs
5 class

Scenario 6

8000 ft
-12 dgs
625 mph
13 m
1.4 MHz
30 mi
30 mi
8 dgs
8 class
19000 ft
-8 dgs
700 mph
35 m
1.8 MHz
13 mi
5 mi
3 dgs
5 class

Scenario 7

29000 ft
-9 dgs
740 mph
24 m
1.5 MHz
23 mi
175 mi
16 dgs
9 class
17000 ft
12 dgs
400 mph
16 m
0.4 MHz
15 mi
72 mi
18 dgs
2 class

Scenario 8

22000 ft
-14 dgs
775 mph
30 m
1.5 MHz
25 mi
14 mi
6 dgs
9 class
23000 ft
-2 dgs
475 mph
52 m
1.1 MHz
15 mi
87 mi
14 dgs
7 class

Scenario 9

9000 ft
-7 dgs
790 mph
11 m
1.1 MHz
27 mi
9 mi
4 dgs
8 class
13000 ft
1 dgs
375 mph
29 m
0.2 MHz
17 mi
78 mi
19 dgs
5 class

Scenario 10

16000 ft
-10 dgs
750 mph
17 m
1.7 MHz
25 mi
32 mi
12 dgs
8 class
10000 ft
-2 dgs
450 mph
14 m
0.9 MHz
30 mi
22 mi
15 dgs
4 class

Appendix C

SAMPLE DATA FILES

DATA FILE EXTRACTS

Each experiment session comprised 10 trials for which four data files (Subject Snapshot, Subject Summary, Wizard Snapshot, and Wizard Summary) were generated. The following excerpts represent a single trial for one participant.

Subject Snapshot File for Participant 2113104

Trial = 1
Time = 188 Requests wiz 1 threat 1 attr 1
Time = 283 Subj Mach knows wiz sending first response for wiz 1 threat 1 attr 1
Time = 366 Subj received ackn from wiz 1 threat 1 attr 1
Time = 370 Requests wiz 2 threat 1 attr 5
Time = 436 Subj Mach knows wiz sending first response for wiz 2 threat 1 attr 5
Time = 552 Subj received ackn from wiz 2 threat 1 attr 5
Time = 717 Subj received reply from wiz 2 threat 1 attr 5
Time = 839 Subj received reply from wiz 1 threat 1 attr 1
Time = 842 Selected priority V wiz 1 threat 1 attr IFF
Correct threat level is V
Time = 846 Entering text for wiz 2 threat 1 attr 5:24
Time = 904 Entering text for wiz 1 threat 1 attr 1:11000
Time = 1468 Selected priority S wiz 1 threat 2 attr IFF
Correct threat level is S
Time = 1540 Requests wiz 1 threat 2 attr 1
Time = 1600 Requests wiz 2 threat 2 attr 5
Time = 1649 Subj Mach knows wiz sending first response for wiz 1 threat 2 attr 1
Time = 1719 Subj received ackn from wiz 1 threat 2 attr 1
Time = 1857 Subj received reply from wiz 1 threat 2 attr 1
Time = 1878 Entering text for wiz 1 threat 2 attr 1:21000
Time = 2076 Requests wiz 2 threat 2 attr 5
Time = 2139 Requests wiz 1 threat 2 attr 2
Time = 2155 Subj Mach knows wiz sending first response for wiz 2 threat 2 attr 5
Time = 2270 Subj received ackn from wiz 2 threat 2 attr 5
Time = 2424 Subj received reply from wiz 2 threat 2 attr 5
Time = 2424 Subj Mach knows wiz sending first response for wiz 1 threat 2 attr 2
Time = 2493 Subj received ackn from wiz 1 threat 2 attr 2
Time = 2497 Entering text for wiz 2 threat 2 attr 5:18
Time = 2784 Requests wiz 2 threat 2 attr 6
Time = 2873 Subj Mach knows wiz sending first response for wiz 2 threat 2 attr 6
Time = 2988 Subj received ackn from wiz 2 threat 2 attr 6
Time = 3093 Subj received reply from wiz 1 threat 2 attr 2
Time = 3121 Entering text for wiz 1 threat 2 attr 2:2
Time = 3325 Subj received reply from wiz 2 threat 2 attr 6
Time = 3328 Entering text for wiz 2 threat 2 attr 6:80
Time = 3767 Selected priority V wiz 1 threat 1 attr 1
Correct threat level is V
Time = 4071 Selected priority V wiz 2 threat 1 attr 5
Correct threat level is V
Time = 4146 Requests wiz 1 threat 1 attr 2
Time = 4211 Requests wiz 2 threat 1 attr 6
Time = 4312 Subj Mach knows wiz sending first response for wiz 1 threat 1 attr 2

Time = 4381 Subj received ackn from wiz 1 threat 1 attr 2
Time = 4495 Subj received reply from wiz 1 threat 1 attr 2
Time = 4495 Subj Mach knows wiz sending first response for wiz 2 threat 1 attr 6
Time = 4611 Subj received ackn from wiz 2 threat 1 attr 6
Time = 4767 Subj received reply from wiz 2 threat 1 attr 6
Time = 4771 Selected priority S wiz 1 threat 1 attr 2
Correct threat level is S
Time = 5098 Selected priority V wiz 2 threat 1 attr 6
Correct threat level is V
Time = 5245 Requests wiz 1 threat 1 attr 3
Time = 5291 Requests wiz 2 threat 1 attr 7
Time = 5422 Subj Mach knows wiz sending first response for wiz 1 threat 1 attr 3
Time = 5491 Subj received ackn from wiz 1 threat 1 attr 3
Time = 5647 Subj received reply from wiz 1 threat 1 attr 3
Time = 5647 Subj Mach knows wiz sending first response for wiz 2 threat 1 attr 7
Time = 5763 Subj received ackn from wiz 2 threat 1 attr 7
Time = 5910 Subj received reply from wiz 2 threat 1 attr 7
Time = 5913 Entering text for wiz 1 threat 1 attr 3:625
Time = 5992 Entering text for wiz 2 threat 1 attr 7:5
Time = 6307 Selected priority V wiz 1 threat 1 attr 3
Correct threat level is V
Time = 6544 Selected priority V wiz 2 threat 1 attr 7
Correct threat level is V
Time = 6641 Requests wiz 1 threat 1 attr 4
Time = 6711 Requests wiz 2 threat 1 attr 8
Time = 6711 Subj Mach knows wiz sending first response for wiz 1 threat 1 attr 4
Time = 6781 Subj received ackn from wiz 1 threat 1 attr 4
Time = 6781 Subj Mach knows wiz sending first response for wiz 2 threat 1 attr 8
Time = 6897 Subj received ackn from wiz 2 threat 1 attr 8
Time = 7245 Subj received reply from wiz 2 threat 1 attr 8
Time = 7332 Subj received reply from wiz 1 threat 1 attr 4
Time = 7336 Entering text for wiz 2 threat 1 attr 8:9
Time = 7376 Entering text for wiz 1 threat 1 attr 4:15
Time = 7701 Selected priority V wiz 1 threat 1 attr 4
Correct threat level is V
Time = 7992 Selected priority V wiz 2 threat 1 attr 8
Correct threat level is V
Time = 9128 Decision E for threat 1
Correct decision is E
Time = 9451 Selected priority S wiz 1 threat 2 attr 1
Correct threat level is S
Time = 9737 Selected priority S wiz 2 threat 2 attr 5
Correct threat level is S
Time = 10056 Selected priority S wiz 2 threat 2 attr 6
Correct threat level is S
Time = 10311 Selected priority S wiz 1 threat 2 attr 2
Correct threat level is S
Time = 10368 Requests wiz 1 threat 2 attr 3
Time = 10418 Subj Mach knows wiz sending first response for wiz 1 threat 2 attr 3
Time = 10487 Subj received ackn from wiz 1 threat 2 attr 3
Time = 10635 Subj received reply from wiz 1 threat 2 attr 3
Time = 10640 Requests wiz 2 threat 2 attr 7
Time = 10643 Entering text for wiz 1 threat 2 attr 3:650
Time = 10724 Subj Mach knows wiz sending first response for wiz 2 threat 2 attr 7
Time = 10839 Subj received ackn from wiz 2 threat 2 attr 7
Time = 11091 Selected priority V wiz 1 threat 2 attr 3
Correct threat level is V
Time = 11156 Requests wiz 1 threat 2 attr 4
Time = 11376 Subj received reply from wiz 2 threat 2 attr 7
Time = 11379 Entering text for wiz 2 threat 2 attr 7:13

Time = 11380 Subj Mach knows wiz sending first response for wiz 1 threat 2 attr 4
Time = 11449 Subj received ackn from wiz 1 threat 2 attr 4
Time = 11753 Subj received reply from wiz 1 threat 2 attr 4
Time = 11757 Selected priority S wiz 2 threat 2 attr 7
Correct threat level is S
Time = 11762 Requests wiz 2 threat 2 attr 8
Time = 11820 Requests wiz 1 threat 2 attr 4
Time = 11852 Entering text for wiz 1 threat 2 attr 4:27
Time = 12019 Subj Mach knows wiz sending first response for wiz 1 threat 2 attr 4
Time = 12088 Subj received ackn from wiz 1 threat 2 attr 4
Time = 12234 Requests wiz 2 threat 2 attr 8
Time = 12276 Subj Mach knows wiz sending first response for wiz 2 threat 2 attr 8
Time = 12391 Subj received ackn from wiz 2 threat 2 attr 8
Time = 12496 Subj received reply from wiz 1 threat 2 attr 4
Time = 12755 Selected priority S wiz 1 threat 2 attr 4
Correct threat level is S
Time = 12950 Subj received reply from wiz 2 threat 2 attr 8
Time = 13430 Selected priority S wiz 2 threat 2 attr 8
Correct threat level is S
Time = 14611 Decision W for threat 2
Correct decision is W
Time = 14621 Subj Mach told to clean up trial.
Time = 14648 Successfully ended trial.

Subject Summary File for Participant 2113104

Trial = 1
Mode = VAVR
Target 1 decision is Engage
Target 2 decision is Watch
Attr 1-9 are threat 1 and attr 10-18 are threat 2.
Attributes 15, 8, 0 and 12 have a short delay.
Attributes 10, 16, 17 and 3 have a long delay.
Elapsed time= 14611
The decision for threat 1 was E
The decision for threat 2 was W
Requests for threat 1 attr 1=1
Requests for threat 1 attr 2=1
Requests for threat 1 attr 3=1
Requests for threat 1 attr 4=1
Requests for threat 1 attr 5=1
Requests for threat 1 attr 6=1
Requests for threat 1 attr 7=1
Requests for threat 1 attr 8=1
Requests for threat 2 attr 1=1
Requests for threat 2 attr 2=1
Requests for threat 2 attr 3=1
Requests for threat 2 attr 4=2
Requests for threat 2 attr 5=2
Requests for threat 2 attr 6=1
Requests for threat 2 attr 7=1
Requests for threat 2 attr 8=2
Priority selected for threat 1 attr 1=1
Priority selected for threat 1 attr 2=1
Priority selected for threat 1 attr 3=1
Priority selected for threat 1 attr 4=1
Priority selected for threat 1 attr 5=1
Priority selected for threat 1 attr 6=1
Priority selected for threat 1 attr 7=1
Priority selected for threat 1 attr 8=1

Priority selected for threat 2 attr 1=1
Priority selected for threat 2 attr 2=1
Priority selected for threat 2 attr 3=1
Priority selected for threat 2 attr 4=1
Priority selected for threat 2 attr 5=1
Priority selected for threat 2 attr 6=1
Priority selected for threat 2 attr 7=1
Priority selected for threat 2 attr 8=1
Priority changes for threat 1 attr 1=0
Priority changes for threat 1 attr 2=0
Priority changes for threat 1 attr 3=0
Priority changes for threat 1 attr 4=0
Priority changes for threat 1 attr 5=0
Priority changes for threat 1 attr 6=0
Priority changes for threat 1 attr 7=0
Priority changes for threat 1 attr 8=0
Priority changes for threat 2 attr 1=0
Priority changes for threat 2 attr 2=0
Priority changes for threat 2 attr 3=0
Priority changes for threat 2 attr 4=0
Priority changes for threat 2 attr 5=0
Priority changes for threat 2 attr 6=0
Priority changes for threat 2 attr 7=0
Priority changes for threat 2 attr 8=0
Accessed text box for threat 1 attr 1=1
Accessed text box for threat 1 attr 2=0
Accessed text box for threat 1 attr 3=1
Accessed text box for threat 1 attr 4=1
Accessed text box for threat 1 attr 5=1
Accessed text box for threat 1 attr 6=0
Accessed text box for threat 1 attr 7=1
Accessed text box for threat 1 attr 8=1
Accessed text box for threat 2 attr 1=1
Accessed text box for threat 2 attr 2=1
Accessed text box for threat 2 attr 3=1
Accessed text box for threat 2 attr 4=1
Accessed text box for threat 2 attr 5=1
Accessed text box for threat 2 attr 6=1
Accessed text box for threat 2 attr 7=1
Accessed text box for threat 2 attr 8=0

Wizard Snapshot File for Participant 2113104

Trial = 1
Mode= VAVR
Time = 187 Mach knows subj asks for attr value for wiz 1 threat 1 attr 1
Time = 278 Reply Button wiz 1 threat 1 attr 1
Time = 280 Mach sends Reply & ackn to wiz 1 for threat 1 attr 1
Time = 370 Mach knows subj asks for attr value for wiz 2 threat 1 attr 5
Time = 434 Reply Button wiz 2 threat 1 attr 5
Time = 435 Mach sends Reply & ackn to wiz 2 for threat 1 attr 5
Time = 858 Ackn Button wiz 2 threat 1 attr 5
Time = 964 Ackn Button wiz 1 threat 1 attr 1
Time = 1218 Mach knows to set alert for wiz 2 threat 1 attr 5
Time = 1218 Mach knows to cancel alert for wiz 2 threat 1 attr 5
Time = 1339 Mach knows to set alert for wiz 1 threat 1 attr 1
Time = 1340 Mach knows to cancel alert for wiz 1 threat 1 attr 1
Time = 1541 Mach knows subj asks for attr value for wiz 1 threat 2 attr 1
Time = 1601 Mach knows subj asks for attr value for wiz 2 threat 2 attr 5 but denied because 2nd request attr.
Time = 1646 Reply Button wiz 1 threat 2 attr 1

Time = 1648 Mach sends Reply & ackn to wiz 1 for threat 2 attr 1
Time = 1976 Ackn Button wiz 1 threat 2 attr 1
Time = 2077 Mach knows subj asks for attr value for wiz 2 threat 2 attr 5
Time = 2140 Mach knows subj asks for attr value for wiz 1 threat 2 attr 2
Time = 2153 Reply Button wiz 2 threat 2 attr 5
Time = 2155 Mach sends Reply & ackn to wiz 2 for threat 2 attr 5
Time = 2248 Reply Button wiz 1 threat 2 attr 2
Time = 2250 Mach sends Reply & ackn to wiz 1 for threat 2 attr 2
Time = 2496 Mach knows to set alert for wiz 1 threat 2 attr 1
Time = 2497 Mach knows to cancel alert for wiz 1 threat 2 attr 1
Time = 2557 Ackn Button wiz 2 threat 2 attr 5
Time = 2787 Mach knows subj asks for attr value for wiz 2 threat 2 attr 6
Time = 2874 Reply Button wiz 2 threat 2 attr 6
Time = 2875 Mach sends Reply & ackn to wiz 2 for threat 2 attr 6
Time = 3098 Mach knows to set alert for wiz 2 threat 2 attr 5
Time = 3099 Mach knows to cancel alert for wiz 2 threat 2 attr 5
Time = 3182 Ackn Button wiz 1 threat 2 attr 2
Time = 3391 Ackn Button wiz 2 threat 2 attr 6
Time = 3599 Mach knows to set alert for wiz 1 threat 2 attr 2
Time = 3599 Mach knows to cancel alert for wiz 1 threat 2 attr 2
Time = 3829 Mach knows to set alert for wiz 2 threat 2 attr 6
Time = 3830 Mach knows to cancel alert for wiz 2 threat 2 attr 6
Time = 4151 Mach knows subj asks for attr value for wiz 1 threat 1 attr 2
Time = 4215 Mach knows subj asks for attr value for wiz 2 threat 1 attr 6
Time = 4314 Reply Button wiz 1 threat 1 attr 2
Time = 4316 Mach sends Reply & ackn to wiz 1 for threat 1 attr 2
Time = 4369 Reply Button wiz 2 threat 1 attr 6
Time = 4371 Mach sends Reply & ackn to wiz 2 for threat 1 attr 6
Time = 4625 Ackn Button wiz 1 threat 1 attr 2
Time = 4943 Ackn Button wiz 2 threat 1 attr 6
Time = 5000 Mach knows to set alert for wiz 1 threat 1 attr 2
Time = 5001 Mach knows to cancel alert for wiz 1 threat 1 attr 2
Time = 5251 Mach knows subj asks for attr value for wiz 1 threat 1 attr 3
Time = 5274 Mach knows to set alert for wiz 2 threat 1 attr 6
Time = 5274 Mach knows to cancel alert for wiz 2 threat 1 attr 6
Time = 5297 Mach knows subj asks for attr value for wiz 2 threat 1 attr 7
Time = 5425 Reply Button wiz 1 threat 1 attr 3
Time = 5426 Mach sends Reply & ackn to wiz 1 for threat 1 attr 3
Time = 5503 Reply Button wiz 2 threat 1 attr 7
Time = 5505 Mach sends Reply & ackn to wiz 2 for threat 1 attr 7
Time = 5866 Ackn Button wiz 1 threat 1 attr 3
Time = 6016 Ackn Button wiz 2 threat 1 attr 7
Time = 6155 Mach knows to set alert for wiz 1 threat 1 attr 3
Time = 6155 Mach knows to cancel alert for wiz 1 threat 1 attr 3
Time = 6418 Mach knows to set alert for wiz 2 threat 1 attr 7
Time = 6418 Mach knows to cancel alert for wiz 2 threat 1 attr 7
Time = 6649 Mach knows subj asks for attr value for wiz 1 threat 1 attr 4
Time = 6713 Reply Button wiz 1 threat 1 attr 4
Time = 6715 Mach sends Reply & ackn to wiz 1 for threat 1 attr 4
Time = 6720 Mach knows subj asks for attr value for wiz 2 threat 1 attr 8
Time = 6777 Reply Button wiz 2 threat 1 attr 8
Time = 6779 Mach sends Reply & ackn to wiz 2 for threat 1 attr 8
Time = 7340 Ackn Button wiz 2 threat 1 attr 8
Time = 7429 Ackn Button wiz 1 threat 1 attr 4
Time = 7754 Mach knows to set alert for wiz 2 threat 1 attr 8
Time = 7755 Mach knows to cancel alert for wiz 2 threat 1 attr 8
Time = 7841 Mach knows to set alert for wiz 1 threat 1 attr 4
Time = 7842 Mach knows to cancel alert for wiz 1 threat 1 attr 4
Time = 10377 Mach knows subj asks for attr value for wiz 1 threat 2 attr 3
Time = 10422 Reply Button wiz 1 threat 2 attr 3

Time = 10424 Mach sends Reply & ackn to wiz 1 for threat 2 attr 3
Time = 10648 Mach knows subj asks for attr value for wiz 2 threat 2 attr 7
Time = 10730 Reply Button wiz 2 threat 2 attr 7
Time = 10731 Mach sends Reply & ackn to wiz 2 for threat 2 attr 7
Time = 10788 Ackn Button wiz 1 threat 2 attr 3
Time = 11146 Mach knows to set alert for wiz 1 threat 2 attr 3
Time = 11146 Mach knows to cancel alert for wiz 1 threat 2 attr 3
Time = 11167 Mach knows subj asks for attr value for wiz 1 threat 2 attr 4
Time = 11246 Reply Button wiz 1 threat 2 attr 4
Time = 11248 Mach sends Reply & ackn to wiz 1 for threat 2 attr 4
Time = 11471 Ackn Button wiz 2 threat 2 attr 7
Time = 11772 Mach knows subj asks for attr value for wiz 2 threat 2 attr 8 but denied because 2nd request attr.
Time = 11830 Mach knows subj asks for attr value for wiz 1 threat 2 attr 4
Time = 11886 Mach knows to set alert for wiz 2 threat 2 attr 7
Time = 11887 Mach knows to cancel alert for wiz 2 threat 2 attr 7
Time = 11977 Ackn Button wiz 1 threat 2 attr 4
Time = 12024 Reply Button wiz 1 threat 2 attr 4
Time = 12028 Mach sends Reply & ackn to wiz 1 for threat 2 attr 4
Time = 12245 Mach knows subj asks for attr value for wiz 2 threat 2 attr 8
Time = 12263 Mach knows to set alert for wiz 1 threat 2 attr 4
Time = 12264 Mach knows to cancel alert for wiz 1 threat 2 attr 4
Time = 12283 Reply Button wiz 2 threat 2 attr 8
Time = 12285 Mach sends Reply & ackn to wiz 2 for threat 2 attr 8
Time = 13007 Mach knows to set alert for wiz 1 threat 2 attr 4
Time = 13008 Mach knows to cancel alert for wiz 1 threat 2 attr 4
Time = 13081 Ackn Button wiz 2 threat 2 attr 8
Time = 13204 Ackn Button wiz 1 threat 2 attr 4
Time = 13461 Mach knows to set alert for wiz 2 threat 2 attr 8
Time = 13462 Mach knows to cancel alert for wiz 2 threat 2 attr 8
Time = 14632 Mach knows subj made both decisions.
Time = 15277 Ending Trial 1

Wizard Summary File for Participant 2113104

Trial = 1
Mode= VAVR
Threat 2 Attr 8 and Threat 2 Attr 5 for Wiz 2
require a second request before reply is made.
Number of alarms for Wiz 1= 0
Number of alarms for Wiz 2= 0
Number of AttrRequest for threat 1 and attr 1 = 1
Number of AttrRequest for threat 1 and attr 2 = 1
Number of AttrRequest for threat 1 and attr 3 = 1
Number of AttrRequest for threat 1 and attr 4 = 1
Number of AttrRequest for threat 1 and attr 5 = 1
Number of AttrRequest for threat 1 and attr 6 = 1
Number of AttrRequest for threat 1 and attr 7 = 1
Number of AttrRequest for threat 1 and attr 8 = 1
Number of AttrRequest for threat 2 and attr 1 = 1
Number of AttrRequest for threat 2 and attr 2 = 1
Number of AttrRequest for threat 2 and attr 3 = 1
Number of AttrRequest for threat 2 and attr 4 = 2
Number of AttrRequest for threat 2 and attr 5 = 2
Number of AttrRequest for threat 2 and attr 6 = 1
Number of AttrRequest for threat 2 and attr 7 = 1
Number of AttrRequest for threat 2 and attr 8 = 2
Number of AcknRec selected for threat 1 attr 1 = 1
Number of AcknRec selected for threat 1 attr 2 = 1
Number of AcknRec selected for threat 1 attr 3 = 1

Number of AcknRec selected for threat 1 attr 4 = 1
Number of AcknRec selected for threat 1 attr 5 = 1
Number of AcknRec selected for threat 1 attr 6 = 1
Number of AcknRec selected for threat 1 attr 7 = 1
Number of AcknRec selected for threat 1 attr 8 = 1
Number of AcknRec selected for threat 2 attr 1 = 1
Number of AcknRec selected for threat 2 attr 2 = 1
Number of AcknRec selected for threat 2 attr 3 = 1
Number of AcknRec selected for threat 2 attr 4 = 2
Number of AcknRec selected for threat 2 attr 5 = 1
Number of AcknRec selected for threat 2 attr 6 = 1
Number of AcknRec selected for threat 2 attr 7 = 1
Number of AcknRec selected for threat 2 attr 8 = 1
The next group will only have values if mode is CA or if alert in VA.
Number of AcknRec highlited for threat 1 attr 1 = 1
Number of AcknRec highlited for threat 1 attr 2 = 1
Number of AcknRec highlited for threat 1 attr 3 = 1
Number of AcknRec highlited for threat 1 attr 4 = 1
Number of AcknRec highlited for threat 1 attr 5 = 1
Number of AcknRec highlited for threat 1 attr 6 = 1
Number of AcknRec highlited for threat 1 attr 7 = 1
Number of AcknRec highlited for threat 1 attr 8 = 1
Number of AcknRec highlited for threat 2 attr 1 = 1
Number of AcknRec highlited for threat 2 attr 2 = 1
Number of AcknRec highlited for threat 2 attr 3 = 1
Number of AcknRec highlited for threat 2 attr 4 = 2
Number of AcknRec highlited for threat 2 attr 5 = 1
Number of AcknRec highlited for threat 2 attr 6 = 1
Number of AcknRec highlited for threat 2 attr 7 = 1
Number of AcknRec highlited for threat 2 attr 8 = 1
Number of Alerts highlited threat 1 attr 1 = 0
Number of Alerts highlited threat 1 attr 2 = 0
Number of Alerts highlited threat 1 attr 3 = 0
Number of Alerts highlited threat 1 attr 4 = 0
Number of Alerts highlited threat 1 attr 5 = 0
Number of Alerts highlited threat 1 attr 6 = 0
Number of Alerts highlited threat 1 attr 7 = 0
Number of Alerts highlited threat 1 attr 8 = 0
Number of Alerts highlited threat 2 attr 1 = 0
Number of Alerts highlited threat 2 attr 2 = 0
Number of Alerts highlited threat 2 attr 3 = 0
Number of Alerts highlited threat 2 attr 4 = 0
Number of Alerts highlited threat 2 attr 5 = 0
Number of Alerts highlited threat 2 attr 6 = 0
Number of Alerts highlited threat 2 attr 7 = 0
Number of Alerts highlited threat 2 attr 8 = 0
Number of WizReplies for threat 1 attr 1 = 1
Number of WizReplies for threat 1 attr 2 = 1
Number of WizReplies for threat 1 attr 3 = 1
Number of WizReplies for threat 1 attr 4 = 1
Number of WizReplies for threat 1 attr 5 = 1
Number of WizReplies for threat 1 attr 6 = 1
Number of WizReplies for threat 1 attr 7 = 1
Number of WizReplies for threat 1 attr 8 = 1
Number of WizReplies for threat 2 attr 1 = 1
Number of WizReplies for threat 2 attr 2 = 1
Number of WizReplies for threat 2 attr 3 = 1
Number of WizReplies for threat 2 attr 4 = 2
Number of WizReplies for threat 2 attr 5 = 1
Number of WizReplies for threat 2 attr 6 = 1

Number of WizReplies for threat 2 attr 7 = 1
Number of WizReplies for threat 2 attr 8 = 1
The next group will only have values if mode is VA.
Number of Subj verbal Ackns to Wiz for threat 1 attr 1 = 1
Number of Subj verbal Ackns to Wiz for threat 1 attr 2 = 1
Number of Subj verbal Ackns to Wiz for threat 1 attr 3 = 1
Number of Subj verbal Ackns to Wiz for threat 1 attr 4 = 1
Number of Subj verbal Ackns to Wiz for threat 1 attr 5 = 1
Number of Subj verbal Ackns to Wiz for threat 1 attr 6 = 1
Number of Subj verbal Ackns to Wiz for threat 1 attr 7 = 1
Number of Subj verbal Ackns to Wiz for threat 1 attr 8 = 1
Number of Subj verbal Ackns to Wiz for threat 2 attr 1 = 1
Number of Subj verbal Ackns to Wiz for threat 2 attr 2 = 1
Number of Subj verbal Ackns to Wiz for threat 2 attr 3 = 1
Number of Subj verbal Ackns to Wiz for threat 2 attr 4 = 2
Number of Subj verbal Ackns to Wiz for threat 2 attr 5 = 1
Number of Subj verbal Ackns to Wiz for threat 2 attr 6 = 1
Number of Subj verbal Ackns to Wiz for threat 2 attr 7 = 1
Number of Subj verbal Ackns to Wiz for threat 2 attr 8 = 1
Number of things the subject heard but didn't ackn for threat 1 attr 1 = 0
Number of things the subject heard but didn't ackn for threat 1 attr 2 = 0
Number of things the subject heard but didn't ackn for threat 1 attr 3 = 0
Number of things the subject heard but didn't ackn for threat 1 attr 4 = 0
Number of things the subject heard but didn't ackn for threat 1 attr 5 = 0
Number of things the subject heard but didn't ackn for threat 1 attr 6 = 0
Number of things the subject heard but didn't ackn for threat 1 attr 7 = 0
Number of things the subject heard but didn't ackn for threat 1 attr 8 = 0
Number of things the subject heard but didn't ackn for threat 2 attr 1 = 0
Number of things the subject heard but didn't ackn for threat 2 attr 2 = 0
Number of things the subject heard but didn't ackn for threat 2 attr 3 = 0
Number of things the subject heard but didn't ackn for threat 2 attr 4 = 0
Number of things the subject heard but didn't ackn for threat 2 attr 5 = 0
Number of things the subject heard but didn't ackn for threat 2 attr 6 = 0
Number of things the subject heard but didn't ackn for threat 2 attr 7 = 0
Number of things the subject heard but didn't ackn for threat 2 attr 8 = 0
Number of things the subject did not hear and didn't ackn for threat 1 attr 1 = 0
Number of things the subject did not hear and didn't ackn for threat 1 attr 2 = 0
Number of things the subject did not hear and didn't ackn for threat 1 attr 3 = 0
Number of things the subject did not hear and didn't ackn for threat 1 attr 4 = 0
Number of things the subject did not hear and didn't ackn for threat 1 attr 5 = 0
Number of things the subject did not hear and didn't ackn for threat 1 attr 6 = 0
Number of things the subject did not hear and didn't ackn for threat 1 attr 7 = 0
Number of things the subject did not hear and didn't ackn for threat 1 attr 8 = 0
Number of things the subject did not hear and didn't ackn for threat 2 attr 1 = 0
Number of things the subject did not hear and didn't ackn for threat 2 attr 2 = 0
Number of things the subject did not hear and didn't ackn for threat 2 attr 3 = 0
Number of things the subject did not hear and didn't ackn for threat 2 attr 4 = 0
Number of things the subject did not hear and didn't ackn for threat 2 attr 5 = 0
Number of things the subject did not hear and didn't ackn for threat 2 attr 6 = 0
Number of things the subject did not hear and didn't ackn for threat 2 attr 7 = 0
Number of things the subject did not hear and didn't ackn for threat 2 attr 8 = 0

Appendix D

PROGRAM EXECUTION

NETWORKING INSTRUCTIONS

The experiment application was compiled under the Macintosh System 7 operating system. The following descriptions assume operation in that environment.

To run in experiment mode, open the Control Panel *Network* and select *LocalTalk Built-in*. Then click OK in the dialog box concerning network connections. Open the Control Panel *MacTCP* and select *LocalTalk*. Finally restart the machine.

To switch to experiment mode from Open Transport, run the Network Software Selector utility and select *Classic Networking*. Restart the machine and perform the same operations indicated above to run in experiment mode.

To run in internet mode (network with no experiment), open the Control Panel *Network* and select *EtherTalk*. Then click OK in the dialog box concerning network connections. Open the Control Panel *MacTCP* and select *Ethernet*. Note that is *EtherNET*, not *EtherTALK*. Finally restart the machine.

Given the size and amount of information displayed on the screen, the subject code should be run on a Macintosh with at least a 20-inch screen and the wizard code should be run on a Macintosh with at least a 17-inch screen.

First Time Execution

When running the software for the first time on a set of machines, delete the Wizard.pref and Subject.pref files from the Wizard and Subject folders on their respective machines.

On the Subject machine:

1. Double-click the Subject icon. A dialog box will appear requesting the Subject ID number. Enter an ID of eight or fewer characters.
2. The Connection Settings dialog box appears. Select the *AppleTalk ADSP Tool* as the method.
3. In the subsequent dialog box, the Connection Type will display *ADSP*. Enter your name in the Name field and click OK.
4. Select *Practice* or *Real Trial* from the Type Trial menu.
5. Select *Listen* from the Connection menu.

On the Wizard machine:

6. Double-click on the Wizard icon. A dialog box will appear requesting the Subject ID. Enter the same ID used on the Subject machine.
7. The Connection Settings dialog box appears. Select the *AppleTalk ADSP Tool* as the method.
8. In the subsequent dialog box, the name entered on the Subject's Connections Settings will be visible in the box under the Name field. Click on that name and it will appear in the Name field. Click OK.

9. Select *VAVR*, *CAVR*, *VACR*, or *CACR* from the Mode menu. This will cause an empty window to appear, titled to match the mode selected.
10. Select *Connect* from the Connection menu.
11. Select *Start Trial* from the File menu.

The Wizard machine will now display a window with four buttons (Reply, Repeat, AcknRec, and Alert) for each of the eight attributes of the two targets. The Subject machine should display a window with various buttons, check boxes, and text boxes for each of the attributes as well as radio buttons for decision and a crib sheet and formula for making the decisions. Each trial is completed when the participant makes both decisions. At the end of the practice sessions and the experiment sessions, a dialog box appears indicating the decisions made by the participant and the correct decisions.

Once a complete session has executed, the Wizard.pref and Subject.pref files will appear in the Wizard and Subject folder. If they appear on the desktop instead and a connection cannot be made between the machines (a bell will sound), then recompile the code. Once the prefs files are in the correct folder, execution of the Wizard and the Subject will bypass the Connection Settings dialog boxes. If at any time a session needs to be terminated early, select *Quit* from the File menu of either machine. Then select *Disconnect* from the Connection menu and *Quit* from the File menu of the other machine. Failure to *Disconnect* the second machine will corrupt the preference files; they will need to be deleted and new ones created.